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ABSTRACT

This position paper was developed to inform U.S. policymakers of the state of science and technology education in the United States and of the importance of adequate science and technology understanding to the economic competitiveness of the country. Provided in this document are discussions of the national goals of science and technology education in the United States and policy recommendations regarding students, teachers, subject matter, pivotal grade levels, and geographic areas. This paper also identifies six measures from research which illustrate the state of science and technology education. These include: (1) international standing; (2) national trends; (3) trends by gender and ethnicity; (4) science instruction; (5) science teachers; and (6) geographic area. A discussion of the consequences of education policy concludes this paper. (CW)

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THE PRESENT OPPORTUNITY IN EDUCATION

A position paper on the current state of science and technology education in the United States.

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Triangle Coalition for Science and Technology Education

SE 050 165

September 1988

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Triangle
Coalition
for
Science
and
Technology
Education

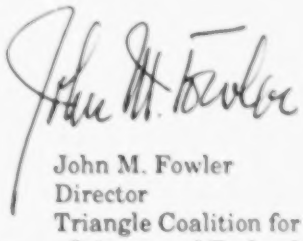
September 1988

PREFACE

"The Present Opportunity in Education" is a position paper of the Triangle Coalition for Science and Technology Education. It was produced by the a task force chaired by Gary Allen, and has been approved by the Triangle Coalition Steering Committee. It is being disseminated pending endorsement by the organizational members of the Triangle Coalition.

This position paper has been developed to inform U.S. policymakers of the distressing state of science and technology education in this country, and of the importance of adequate science and technology understanding to this country's economic competitiveness and democratic processes.

The Triangle Coalition is a Coalition of 75 major national organizations from three broad sectors: business, industry, and labor; science and engineering; and education. These organizations are joined together to increase the effectiveness and efficiency of their efforts to reform science and technology education.



John M. Fowler
Director
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Science and Technology
Education

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THE PRESENT OPPORTUNITY IN EDUCATION

EXECUTIVE SUMMARY

It is time for an explicit national educational policy and decisive federal action to implement the policy. The need for action is especially critical in science and technology education. We cannot afford to have another generation of students who are unprepared to work and live in the technology-driven era of the future.

A NATIONAL GOAL

The nation must set as a goal the development of a broad pool of citizens who are interested and functionally literate in science and its applications in society.

A national science education policy must be sensitive to two broad needs:

- Ensuring that most young people have scientific and technological literacy adequate to cope with the demands placed on an individual by a scientific and technologically-oriented society.
- Providing a deep pool of persons competent to become American leaders in scientific and technological research and development.

POLICY RECOMMENDATIONS

Our fundamental recommendation is that the national science and technology education policy specifically target major areas of identified need.

The policy recommendation of the Triangle Coalition will require a critical balance of federal, state, and local investment by both the public and private sector.

Critical Needs

New programs must be developed, present programs strengthened, and old strategies, which do not address these critical needs reexamined, to achieve the sharp focus required. We have identified the following five specific areas of need, which form the basis for the development of a national policy.

- Students: New programs and curricula are needed to nurture interest and develop skills at all grade levels. Attention needs to be focused on minority students and women.
- Teachers: In addition to the development of a larger pool of highly skilled science teachers, more science teachers must be prepared to instruct students in more than one field of specialization. Priority must be given to the improvement of the science teaching competence of elementary school teachers.
- Subject Matter: The physical sciences are poorly taught in many school districts. A complete reformation of the science curricula for the elementary and middle/junior high years is needed.
- Pivotal Grade Levels: Resources should be concentrated on improving elementary school science for all students and in redirecting and reforming undergraduate science studies.
- Geographic Areas: Resources should be focussed on the inner city schools, and on school districts in rural areas.

A New Constituency

Business/Industry/Labor Partnerships: The promising new movement of community collaboration between the business sector and scientists, engineers, and educators to reform science and technology education should be encouraged with "seed money," tax, and other incentives.

SIX MEASURES TELL THE STORY

1. International Standing

On an identical international science achievement test:

- U.S. ninth graders ranked only slightly above the lowest of the 16 countries tested.

- Advanced, college-bound students scored 13th—last in biology, 11th of 13 in chemistry, and 9th of 13 in physics.

2. National Trends

After a steady decline in the 1970s, especially at age 17, student performance in science, as measured by the NAEP tests, began to improve, but only the 9-year-olds have regained the 1969-70 level of proficiency.

3. Trends by Gender and Ethnicity

The gaps in proficiency scores on the NAEP test have narrowed in the 1980s, but non-Asian minorities and women continue to score significantly lower than their white male peers in each of the age categories tested.

4. Science Instruction

Surveys and research studies suggest that lack of emphasis on science, inappropriate curricula and instruction, poorly equipped classrooms, and inadequately prepared teachers are among the explanations for poor student achievement in science.

5. Science Teachers

- Few elementary school teachers describe themselves as well qualified to teach science.

- Roughly half of all high school science teachers are assigned to teach at least one class outside of their area of major college preparation.

6. Geographic Area

- Students from suburban schools score higher on the NAEP test than do their peers from rural or inner city, (urban) schools at all three grade levels.

- Suburban schools are better equipped for science instruction than are either rural or urban schools.

- In most science areas, suburban high schools are more likely to offer advanced courses than the rural or urban high schools.

CONSEQUENCES

Europe, and especially, Japan, Korea, and other Asian countries have workers with more than adequate skills who are willing to work longer hours at lower pay than U.S. workers.

To compete with countries like West Germany, Japan, and Korea we must make a choice; a choice between two futures:

- We can upgrade the skills of a few workers in high-tech production jobs, and consign the rest to lower skilled jobs at low pay, lowering the overall standard of living.

OR

- We can change our goals of production from goods to designs, technical services, and high-tech products with a corresponding change in the status and role of the worker. It is clear that the rich societies of the future will be those countries with high productivity and knowledge-based goods and services, countries that have large numbers of "highly skilled" workers using the most advanced technology available.

If we choose the high wage, high standard of living alternative, then we face a massive education challenge calling for immediate and substantial investment.

The challenge to science educators is quite specific, for science education bears much of the responsibility for developing the key skills for a high technology future. Success will be ensured with the implementation of a policy of targeted support of critical areas of need. With such support, science education **can** produce students with an understanding of the basics of science and mathematics, and the ability to apply them to the solution of technical and societal problems. The nation **can** prepare itself for a high technology future. The price of failure is to continue to slide toward a lower standard of living, and a second class world status.

THE PRESENT OPPORTUNITY IN EDUCATION

The nation is poised at a decision point. A strong national consensus has developed on the social, economic, and competitive necessity for the improvement of education. It is time for an explicit national educational policy and decisive federal action to implement the policy. The need for action is especially critical in science and technology education. We cannot afford to have another generation of students who are unprepared to work and live in the technology-driven era of the future. From an early report on the present condition:

> **"The nation that dramatically and boldly led the world into the age of technology is failing to provide its own children with the intellectual tools needed for the 21st century."**

The National Science Board Commission on Precollege Education in Science, Mathematics and Technology in *Educating Americans for the 21st Century*, 1983.

Too many American citizens are functionally illiterate in science and technology. This reduces their productivity in technical industries and their ability to play an informed role in social and political decisions with scientific/technological content. Furthermore, the talent pool of excellent U.S students planning for careers in science and engineering is shrinking while foreign students are eagerly filling their places in graduate schools.

This national failure has a direct cost to American industries. A significant amount of the $30 billion, which industry spends annually on training and personnel development, is caused by poor school preparation. In fact, business and industry spend as much annually on the most basic remedial education of employees as the federal government spends on science and mathematics education—and still the product is flawed. Unless drastic reform is brought about, we will see the loss of our industrial supremacy and of the vitality of our democratic processes. The fundamental needs in science and technology education are national in scope; the consequences of our continuing failure will be borne by all.

Thus, a large part of the responsibility for providing adequate resources for innovations and leverage for change in the nation's schools belongs to the federal government. But, despite overwhelming data from a multitude of well-researched studies, (some of which are included in this paper), our nation has yet to develop a comprehensive national policy for investment in science and technology education. While reforms have been undertaken at the local and state levels, and new federal legislation has been passed, a statement of national policy needs to be developed with focussed programs, clear goals, and adequate funding.

A NATIONAL GOAL

The nation must set as a goal the development of a broad pool of citizens who are interested and functionally literate in science and its applications in society.

The Triangle Coalition for Science and Technology Education has identified the key components of such a policy. We offer them here to help focus the national agenda in education on the improvement of science and technology, and specifically to provide guidance for increased and redirected federal spending for science and technology education.

We propose a policy with both short- and long-term significance. Program strategies to implement such a policy must explore options for fundamental educational change, as well as encourage adoption of exemplary programs that have been successful in schools.

A national science education policy must be sensitive to two broad needs:

- Ensuring that most young people have scientific and technological literacy adequate to cope with the demands placed on an individual by a scientific and technologically oriented society.

- Providing a deep pool of persons competent to become American leaders in scientific and technological research and development.

The policy response to these needs must be balanced and pursued in the context of enhanced public appreciation for the benefits of science and technology to the nation. The policy recommendations of the Triangle Coalition will require a critical balance of federal, state, and local investment by both public and private sectors.

POLICY RECOMMENDATIONS

Our fundamental recommendation is that the national science and technology education policy specifically target major areas of identified need.

The present politically driven programs, by evenly spreading assistance over all science disciplines, school districts, geographic areas, and grade levels result in a resource base at the point of need, which is too thin to nurture significant improvement. More than increasing the resource pool is needed. Resources must be concentrated where need is great **and** expectation of improvement is realistic.

The federal government must undertake major new responsibilities. The bulk of the effort, however, and most of the resources, will continue to be developed and focused at the local level. In particular, the promising new movement of broad-based, community collaborations, in the reform and support of science and technology education, should be deliberately stimulated and supported. Business/industry and others in the technical community must be encouraged to collaborate with educators in all phases of program development and implementation.

Critical Needs

New programs must be developed, present programs strengthened, and old strategies, which do not address these critical needs reexamined, to achieve the sharp focus required. We have identified the following five specific areas of need, which form the basis for the development of a national policy.

- Under-served students
- Inadequately prepared teachers
- Crucial subject matter areas
- Pivotal grade levels
- Neglected geographic areas.

1. Students

As the data we present in the following sections show, only a few U.S. students are performing successfully in school science, but the problem is critical for certain types of students. Initiatives must be developed to open science and technology to women, Blacks, Native Americans, Hispanics, and other minority populations presently underrepresented in technical/science courses and careers. A variety of strategies will be needed including early childhood programs for the economically disadvantaged. New science and technology curricula, with careful focus on the elementary level, need to be developed, and science and technology education must be consciously structured to nurture interest and develop skills at all grade levels.

2. Teachers

Programs must be devised to produce a pool of highly skilled science teachers, and to keep them current as their disciplines (and the techniques of teaching) grow and change. Many of these teachers must be adequately prepared to instruct students in more than one field of science. Priority must be given to increasing the representation, among science teachers, of the minority populations that will be an increasing percentage of the student body.

A priority effort must be given to reform of pre- and in-service education to bring elementary teaching in science and technology to a satisfactory level of competence.

Although the federal government must increase its funding of pre- and in-service education, there are many other mechanisms including programs at museums and the community-based "local alliances" described in the following section, which deserve encouragement and support.

3. Subject Matter

The physical sciences, including physics, chemistry, and the earth and space sciences are poorly presented in most school districts. There are serious shortages of adequately prepared teachers, and of the time and facilities to enable teachers to do these sciences with their students.

There is a corresponding need for new curricula materials in all areas, which present science and technology as an integrated and interactive area of learning. This curriculum must not only relate classroom teaching to the world that the students inhabit, but also must produce graduates with both the interest and the skills to continue to learn about science and its applications. This purpose is not being served by the present system of courses based on encyclopedic textbooks.

4. Pivotal Grade Levels

Deficiencies in science and technology education are most serious at the elementary level. The filtering off of minority students and women begins at this level. If only for this reason, resources for change must be concentrated here.

Undergraduate science and technology instruction is also in need of redirection and reform. U.S. colleges and universities must be encouraged and given the resources to make undergraduate science and technology instruction appropriate for future teachers, lawyers, managers, and other professionals. These institutions must also be encouraged, if not required, to develop programs and student incentives, which will guide more U.S. students, in particular women and minority students, into careers in science and engineering.

5. Geographic Areas

The waste of human resources is most obvious in the inner city. Educational reform programs of many types must be targeted here. Pay back will come, not only in later increases in productivity, but also in the form of decreased costs of retraining, welfare, law enforcement, and incarceration.

In the rural areas also, resource scarcity, isolation, and inappropriate curricula materials are creating a student population, which is grossly under-served by technical education. In rural America, schools in general, and technical education in particular, offer important opportunities for new careers, community development, and long-term economic growth.

A New Constituency

The growth of "local alliances"—broad-based, community level collaborations to help teachers and schools improve science, mathematics, and technology education—is a new constituency for education, which should be targeted for support and expansion. The Triangle Coalition has developed links with a network of more than 250 such "local alliances," several of them statewide in nature. Much of the support for these local efforts comes from financial or in-kind contributions from business, industry, and labor. These efforts need recognition, "seed money," tax, and other incentives to strengthen existing groups and stimulate the formation of new ones.

We are encouraged that the recently enacted trade bill contains the following wording under Part B, Chapter 4: ". . . to encourage partnerships in science and mathematics education between the business community, museums, libraries, professional mathematics and scientific associations, private nonprofit organizations, appropriate state agencies and elementary and secondary schools." We look forward to the full funding and early establishment of programs under this authorization.

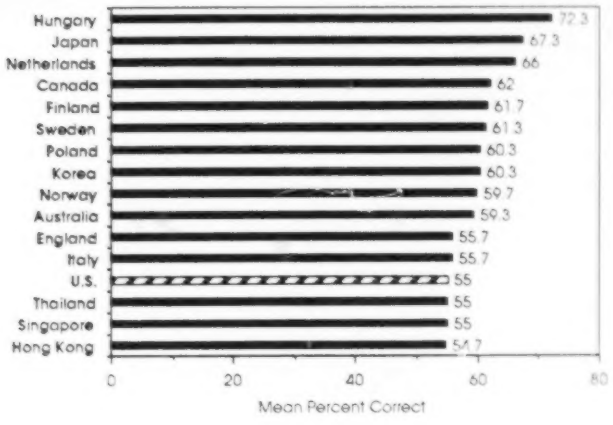
SIX MEASURES TELL THE STORY

To bring the problem into perspective we've selected data from research supported by the National Science Foundation and the U.S. Department of Education. These studies dramatically illustrate needs in each of the policy areas we have identified.

1. International Standing

On an identical international science achievement test, the U.S. ninth grade students ranked only slightly above the lowest of the 16 countries tested, (see Figure 1).

Figure 1. Grade Nine Science Achievement in 16 Countries



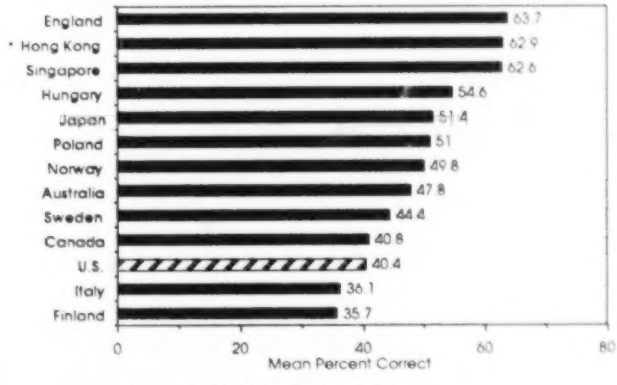
Source: "International Science Report Card" from the second IEA science study, 1988, p.3.

In 1986, U.S. students who were completing a second year of biology, chemistry, or physics were administered, along with students from other countries, a test in their specialty area. These advanced, college bound students scored:

- 13th (last) in biology
- 11th of 13 in chemistry and
- 9th of 13 in physics.

Overall in these three subject areas, U.S. advanced students ranked 11th of the 13 countries tested, (see Figure 2).

Figure 2. Advanced Science Students in Biology, Chemistry, and Physics (average of these tests)



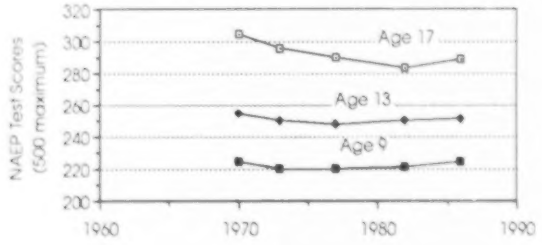
*Hong Kong data is average of two different classes

Source: "International Science Report Card" from the second IEA science study, 1988, composite data pages 4, 5, & 6.

2. National Trends

Performance of 9-, 13-, and 17-year-old students has been measured by the National Assessment of Educational Progress (NAEP) since the 1969-70 school year. After a steady decline in the 1970s, especially at age 17, student performance in science began to improve, but only the 9-year-olds have regained the 1969-70 level of proficiency, (see Figure 3).

Figure 3. National Trends in Average Science Proficiency for 9, 13, and 17-year-olds from 1969-70 to 1986



Source: NAEP data from 1970 to 1986, September 1988.

In addition, in their presentation of these data, the NAEP analysts warn us that most of this improvement has been at the rudimentary level—basic science facts and principles—and that even at the high school level, **"a majority of 17-year-olds are poorly equipped for informed citizenship and productive performance in the work place, let alone post-secondary studies in science."**

3. Trends by Gender and Ethnicity

Most of our scientists and engineers are white males, and by 1990 the talent pool of white males will have shrunk by 30 percent. Bright women and minority students who currently avoid technical careers, for whatever reason, must be brought into that talent pool. Unfortunately, NAEP data offer little encouragement. While the gaps in proficiency scores have narrowed in the 80s, non-Asian minorities and women continue to score significantly lower, than their white male peers, in each of the age categories, (Figures 4 and 5 show this for 17-year-olds).

Figure 4. Trends in Average Science Proficiency for Whites, Blacks, and Hispanics age 17

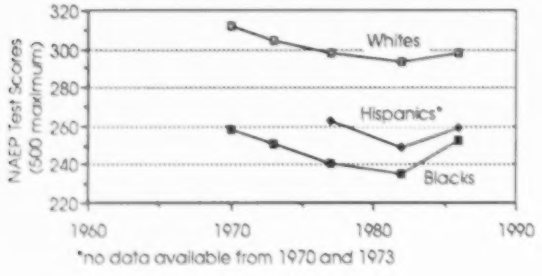
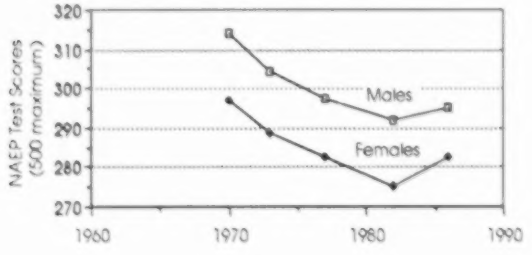


Figure 5. Trends in Average Science Proficiency for Males and Females age 17



Source for Figures 4 & 5: NAEP composite data, September 1988.

4. Science Instruction

Among the possible explanations for poor student achievement are:

- Lack of emphasis on science
- Inappropriate curricula and instruction
- Poorly equipped classrooms
- Inadequately prepared teachers.

Here are some critical facts:*

- Recent national surveys found that 68 percent of students planned to stop taking science classes when minimum school requirements were satisfied.
- Over half of all 17-year-olds indicate that the science they learn in class is not useful in everyday life.

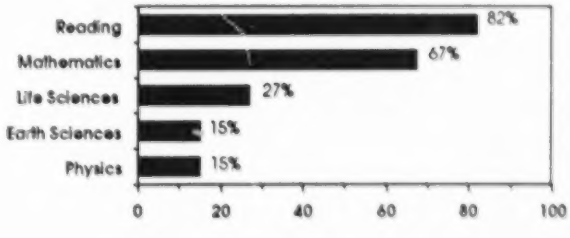
*Source: Weiss, I. R., "1985-86 National Survey of Science and Mathematics Education," November 1987.

- Elementary classes (K-3) typically spend an average of only 18 minutes a day on science, less than half the average time spent on mathematics and one quarter the time spent on reading; upper elementary classes, grades 4-6, spend an average of only 29 minutes a day on science.
- One third of all elementary science classes are taught in classrooms that have no science facilities.
- Eleven percent of the third graders tested by NAEP reported **never** having a science lesson and another 13% reported science lessons less than once a week.
- Nearly half of all seventh grade students report **never** having been asked to interpret data in their science classes. Forty percent or more of both seventh and eleventh grade students report that they have performed no science experiments in the past month.
- The vast majority of teachers and principals believe laboratory-based science classes are more effective than non-laboratory classes, but, overwhelmingly, lecture and discussion are the methods most often used.

5. Science Teachers

Results from teacher self-assessments reveal startling data. While 82% of grade K-6 teachers feel well qualified to teach reading, and 67% to teach mathematics, only 27% believe they are well qualified to teach life science and even fewer to teach physical or earth/space science (15% in each case, see Figure 6).

Figure 6. Percentage of Elementary Teachers Who Believe They are Well Qualified to Teach by Subject Area

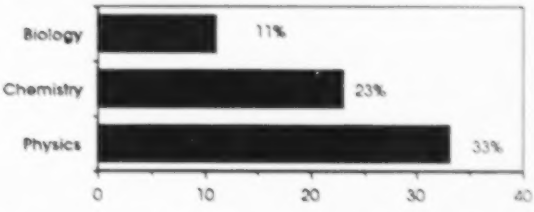


Source: NAEP survey data, September 1988.

It is interesting to note that one half of all the elementary teachers reported they had no in-service science education in the year previous to the assessment.

There is a great deal of "out of field" teaching in American science classes. Roughly half of all high school science teachers are assigned to teach at least one class outside their area of major college preparation. The problem of out-of-field teaching is serious in chemistry and physics, (see Figure 7).

Figure 7. Percentage of High School Classes Taught by Teachers Who did not Major in the Subject

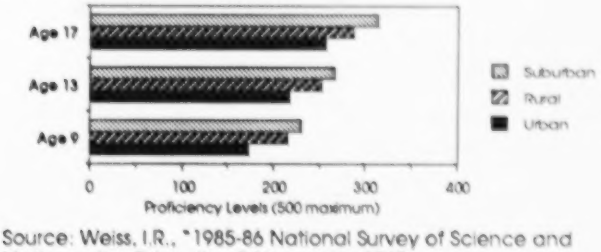


Source: Weiss, I.R., "Course Background Preparation of Science Teachers . . . A Paper Prepared for AAAS Forum on School Science," (1987).

6. Geographic Area

A significant proportion of our precollege students and teachers are in schools and communities where resources for technical education are scarce. This leads to inequality of opportunity and the growing problem of scientific and technological illiteracy among large segments of our youth. The performance differences among students from different geographic conditions are thus substantial. These data show differences much larger for urban-suburban areas than the black-white differences reported above, (see Figure 8).

Figure 8. Average Science Proficiency by Age and Geographic Region (1986)



Source: Weiss, I.R., "1985-86 National Survey of Science and Mathematics Education," November 1987.

Rural and urban elementary science classes are nearly twice as likely as suburban science classes to take place in a classroom with no science facilities, (see Figure 9).

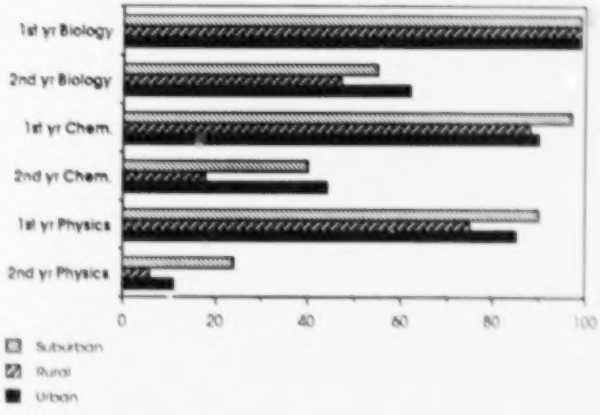
Figure 9. Type of Elementary Science Classrooms (Percent of Classes)

	Suburban	Rural	Urban
Laboratory or special science room.	12%	2%	3%
Classrooms with portable science materials.	61%	53%	52%
Classrooms with no science facilities.	27%	45%	45%

Source: Weiss, I.R., "1985-86 National Survey of Science and Mathematics Education," November 1987.

The differences among geographic areas in terms of both basic and more advanced high school courses normally considered essential to college work in science are shown in Figure 10.

Figure 10. High School Science Course Offerings by Type of Community



Source: Weiss, I.R., "1985-86 National Survey of Science and Mathematics Education," November 1987.

CONSEQUENCES

For most of this century, the United States has been a recognized world leader largely because its industries could out-produce those of any other country. This leadership depended in part on our rich resources of raw materials, but equally important were the production lines where qualified and skilled workers developed, constructed, and marketed high quality, mass-produced, inexpensive products.

Raw materials have now been seriously depleted, and our resource of large numbers of workers with adequate skills is no longer unique. Education has improved all over the world. Now, Europe, and especially Japan, Korea, and other Asian countries have developed mass production capabilities and have workers with more than adequate skills who are willing to work longer hours at lower pay than U.S. workers.

To compete with countries like West Germany, Japan, and Korea we must make a choice; a choice between two futures:

- We can upgrade the skills of a few workers in high-tech production jobs, and consign the rest to lower skilled jobs at low pay, lowering the overall standard of living.

OR

- We can change our goals of production from goods to designs, technical services, and high-tech products with a corresponding change in the status and role of the worker. It is clear that the rich societies of the future will be those countries with high productivity and knowledge-based goods and services, countries that have large numbers of "highly skilled" workers using the most advanced technology available.

If we choose the high wage, high standard of living alternative, we face a massive educational challenge calling for immediate and substantial investment. From the evidence displayed earlier, it is clear that neither our existing work force, nor the one being presently educated in our schools has the technical or the reasoning skills to enable them to become the highly skilled workers that are needed.

The challenge is to prepare a well educated and scientifically literate future work force. Our present work force has a direct financial stake in meeting this challenge. When our parents retired, each of their pensions was supported by 17 workers. When the present "baby boom" generation begins to retire, the ratio will be about three workers per retiree, one of whom, on the average, will be a member of a minority population. To keep pensions healthy each of us needs three highly skilled, highly paid workers supporting us; we cannot afford to have any one of them, at age 50, chronically unemployed in a declining economy.

The challenge to the entire educational system is not an unprecedented one. It is much the same challenge, on a far larger scale, that the nation faced in the last century as we moved from a largely agrarian country to an industrial power. It is a lesson that the rest of the world has learned from us. Nevertheless, no country in history has mandated that the majority of its citizens become and remain well-educated. The numbers we are dealing with, of teachers, schools, and students are staggering and so the increase in the investment that will be needed to accomplish these goals, even if spread over a number of years, will be a large one. But, as Harold Hogkinson has repeatedly warned us, we are moving into a period when young people will be a scarce resource, and with a youth shortage, we cannot afford to let any child fail.

The challenge to science educators is quite specific, for science education bears much of the responsibility for developing the key skills for a high technology future. Success will be ensured with the implementation of a national policy of targeted support of critical areas of need. With such support science educators **can** produce students with an understanding of the basics of science and mathematics and the ability to apply them to the solution of technical and societal problems. The nation **can** prepare itself for a high technology future. The price of failure is to continue to slide toward a lower standard of living, and a second class world status.

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American Association for the Advancement of Science

Kenneth Chapman
American Chemical Society

Kenneth D. Fisher
Federation of American Societies for Experimental Biology

Lynn W. Glass
Iowa Alliance for Science Education

Richard Gowen
Institute of Electrical and Electronics Engineers

Logan E. Hargrove
Acoustical Society of America

Manert Kennedy
Colorado Alliance for Science

Marjorie King
National Association of Biology Teachers

Marsha Levine
American Federation of Teachers

William Linder-Scholer
Cray Research, Inc.

Cornell McCullom, Jr.
National Action Council for Minorities in Engineering, Inc.

Phyllis McGrath
General Electric Company

Boyd Odom
Atlanta Partnership of Business and Education

E. Joe Piel
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Walter Purdy
Edison Electric Institute

Gerald Skoog
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The Triangle Coalition for Science and Technology Education is a 501(c)3 nonprofit organization housed at NSTA, which serves as its fiscal agent. The Triangle Coalition staff operation is headed by Dr. John Fowler, Executive Director. 5112 Berwyn Road, 3rd Floor, College Park, MD 20740, (301) 220-0870.